LCE 2020 Grenoble
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Material and Manufacturing Process Selection for Electronics Eco-Design: Case Study on Paper-Based Water Quality Sensors

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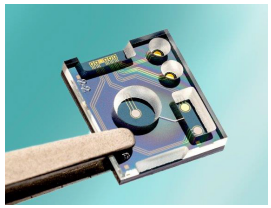
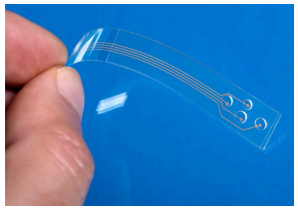
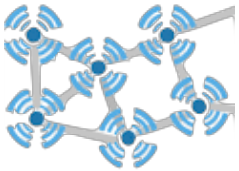
Biosensors for Water Quality Management



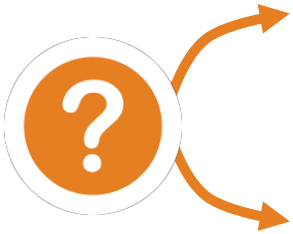


Water quality sensors [Imec, 2018]

Need for **affordable** water quality sensors



Sensor **dissemination**



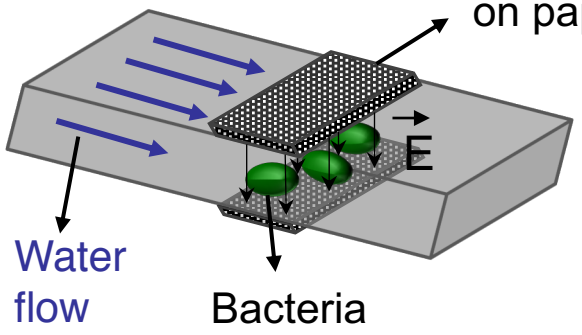
Assess impacts of water sensors

Reduce impacts by **new designs**

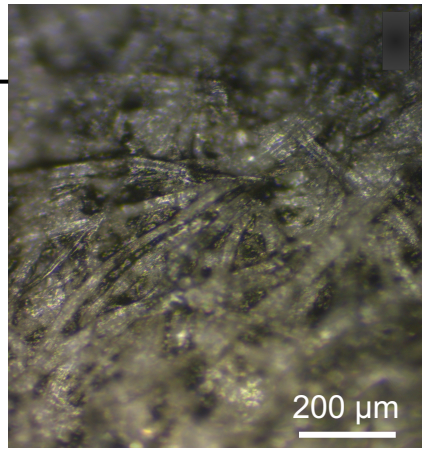
Development of Paper-Based Water Quality Sensors

- Paper: a beneficial platform for biosensors
- **Advantages**
  - Natural capillarity
  - Bio-interface
  - Large surface area
  - Printed electrodes
- Volumetric electro-chemical detection

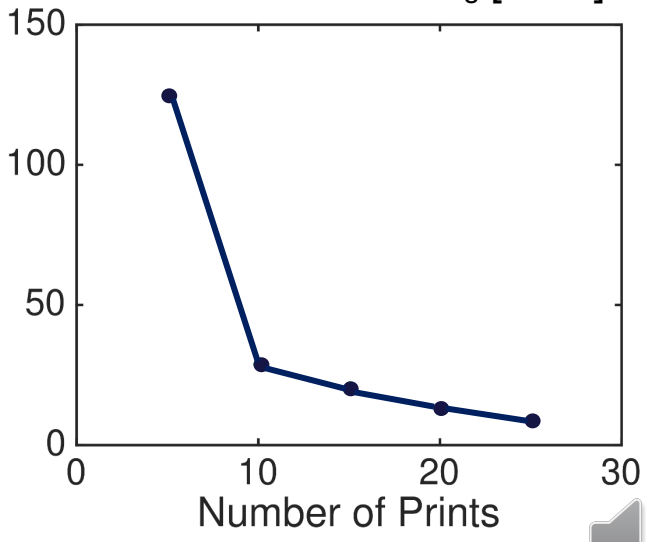
Paper biosensor



Carbon nanotubes



Sheet Resistance R_s [kΩ/□]

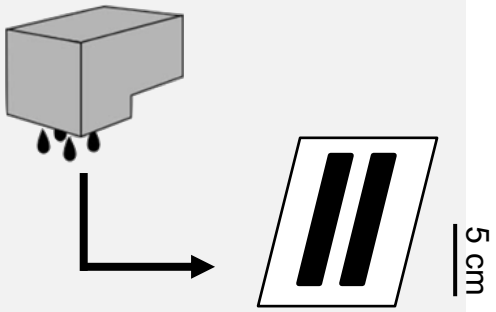


Comparative LCA : Goal

- Help microelectronic engineers in process and material selection for environmental sustainabilty, using simple indicators (energy and CO_2)
- Identification and analysis of **3 routes** for biosensor production :

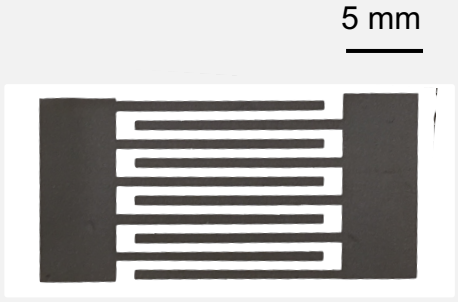
Paper-CNT sensor

- Paper support
- Conventional printer
- Conductive inks (CNTs)



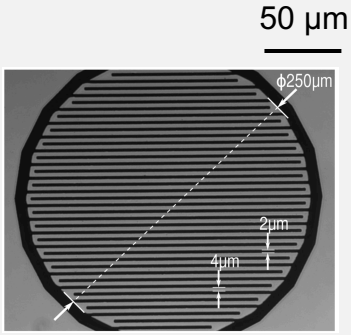
Paper-Al sensor

- Paper support
- Microelectronics fab.
- Aluminum electrodes



Si - biosensor

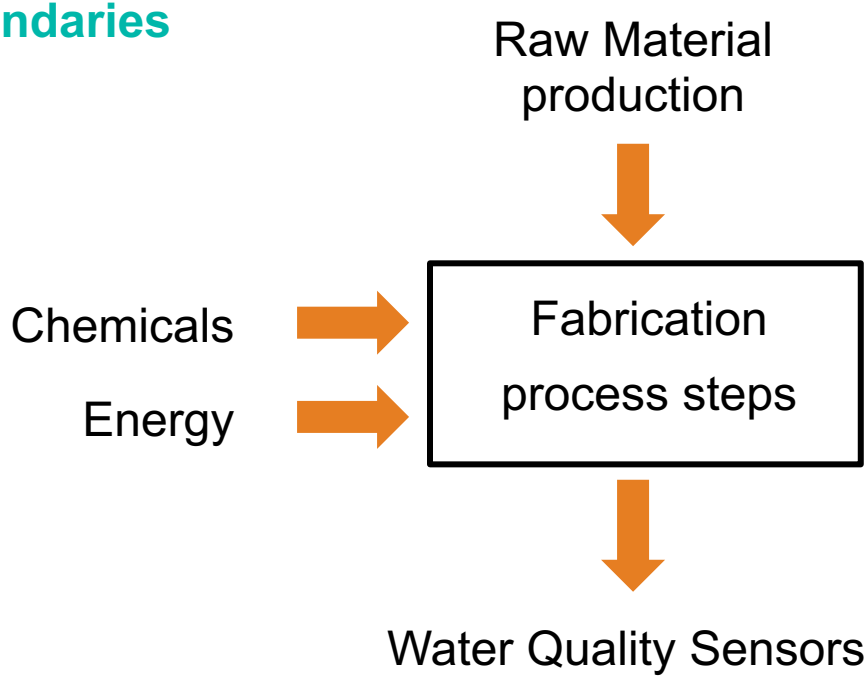
- Silicon support
- Microelectronics fab. (cleanrooms)



[Designed and produced at UCLouvain]

Comparative LCA : Scope

- **Functional Unit** – Performing 1000 water quality measurements (bacteria)
- **Reference Flows** – Materials and energy to produce 1000 sensors
  - Hypothesis of **single-use** sensors (contamination)
- **Boundaries**



Excluded processes
- Infrastructure prod.
- Transportation
- Usage
- End of life treatment

Further studies…

Inputs
- Mass Flows
- Energy

Comparative LCA : Data Inventory

▷ Inventory model

- Embodied Energy $EE = EE_{materials} + EE_{processes} = \sum [m_{mat} \times e\,] + \sum [(m_{chem} \times e) + e_{proc}]$
- Carbon Footprint *idem*

Energy associated with electricity use

Raw material flows [kg]

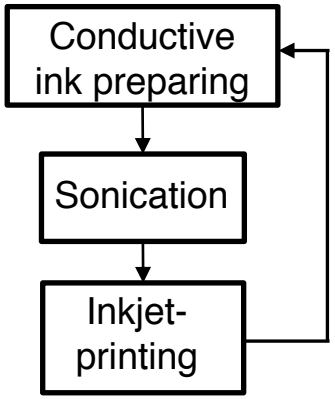
Raw material energy intensities [MJ/kg]

Chemical flows [kg]

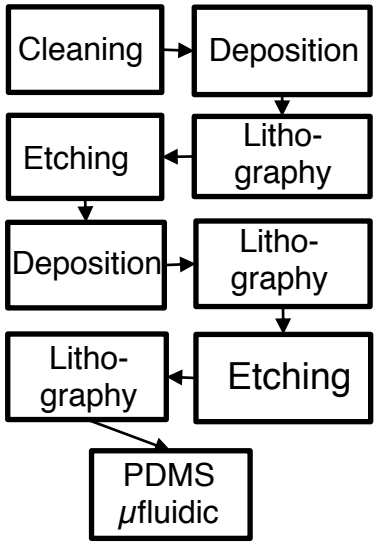
Chemicals energy intensities [MJ/kg]

▷ Process steps

Paper-CNT sensor



Si - biosensor



Data sources ?

Mass flows and energy

- Primary data
- Generic data

Further studies…

Energy and Carbon intensities

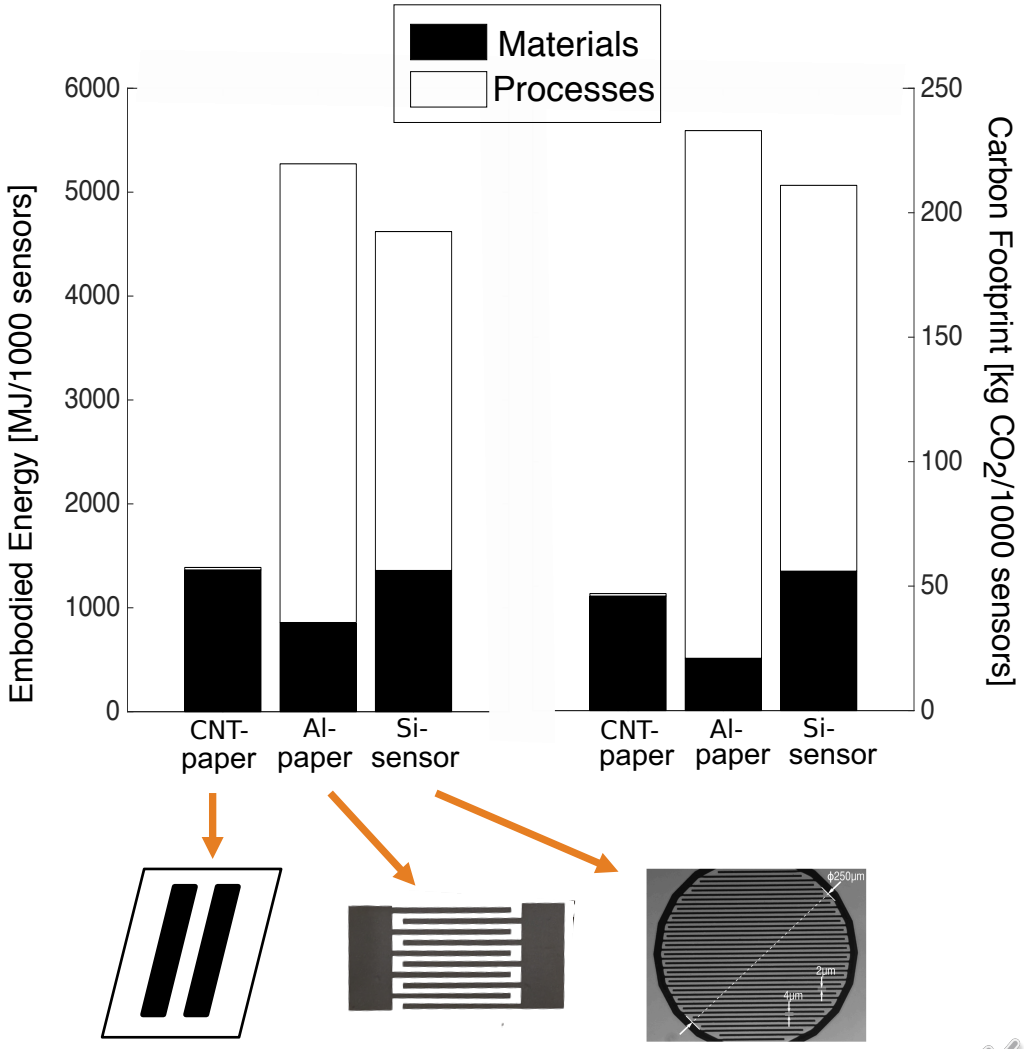
- Commercial database (Granta)

Comparative LCA : Results and Discussion

Main results

- Energy- and emission-intensive cleanroom chemicals and processes
- Carbon nanotubes (CNTs) are responsible for most of the emissions related to the process
- The use of paper as a substitute of silicon decreases the material embodied energy

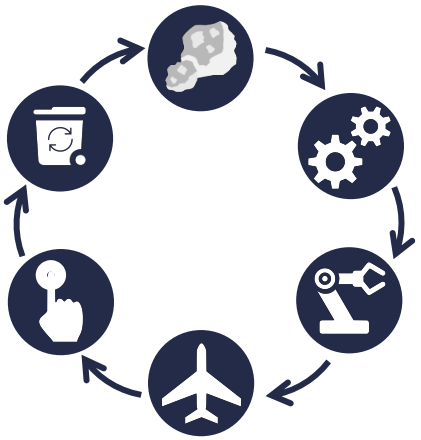
- Conscientious choice of nanomaterials
- Other printing techniques ?



Conclusions and Perspectives

Performed a prospective life cycle analysis to eco-design water quality sensors

- **Technical developments** still required
- Integration of the **end of life** considerations
- Issues revealed in data quality and **data scarcity**
- **Collaboration** with an industry



Thank you !

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